(12)

WT-1310 (EX)
EXTRACTED VERSION

OPERATION REDWING

Project 2.1
Gamma Exposure Versus Distance

May-July 1956

Pacific Proving Grounds

NOTICE

This is an extract of WT-1310, Operation REDWING, which remains classified SECRET/RESTRICTED DATA as of this date.

Extract version prepared for:

Director
DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

1 April 1981

1.3 THEORY

The gamma radiation emitted from a nuclear detonation may be divided into two portions: initial radiation and residual radiation. The residual radiation may include radiation both from fallout and neutron-induced activity. In this report, the radiation emitted during the first 30 seconds is termed initial radiation, and that received after 30 seconds is called residual radiation.

1.3.1 Initial-Gamma Radiation. For a fission-type device the initial radiations are divided approximately as shown in Table 1.1 (from Reference 8). The major contributions to initial-gamma radiation are from the fission-product gammas and from the neutron-capture gammas resulting from the N^{14} (n, γ) N^{15} reaction between device neutrons and atmospheric nitrogen. The prompt gammas are nearly all absorbed in the device itself and are of little significance

TABLE 1.1 ENERGY PARTITION IN FISSION

Reference 8

Mechanism	Percent of Total Fission Energy	Total Energy per Fission
	pct	Mev
Kinetic Energy of Fission Fragments	81	162
Prompt Neutrons	4	8
Prompt Gammas *	4	8
Fission-Product Gammas	2.7	5.4
Fission-Product Betas	2.7	5.4
Fission-Product Neutrinos	5.5	11
Delayed Neutrons	0.1	0.2
Totals	100.0	200.0

* Mostly absorbed in the device

outside the device. The fission-product gammas predominate at close distances (Reference 8). The N^{14} (n, γ) N^{15} gammas become increasingly important at greater distances and eventually become the major contributor. This applies only to devices with yields of less than 100 kt, in which the hydrodynamic effect is small. Figure 1.1 shows the contribution from fission-product gammas and N^{14} (n, γ) N^{15} for a 1-kt surface burst. Therefore, the fission products become a more important source of initial-gamma exposure from high-yield fission-fusion devices at greater distances.

For thermonuclear devices, in addition to gamma radiation from fission-product gammas, it is necessary to consider the interaction of neutrons from the fusion process with N^{14}. The radiation caused by the fusion process may vary over wide limits, depending on the design of the device. For a given yield, the number of neutrons available may be 10 times as great for fusion as for fission, and therefore a large number of gamma photons are contributed by the N^{14} (n, γ) N^{15} reactions (Reference 9). However, because of the short half life, this gamma radiation decays before it can be enhanced by the hydrodynamic effect. Gammas from the longer-lived fission products are greatly enhanced by this effect. Therefore, fission products are the most important source of initial-gamma exposure resulting from high-yield fission-fusion devices. The preceding discussion is also in essential agreement with the expanded treatment given in Reference 10.

1.3.2 Residual-Gamma Radiation. Residual-gamma radiation consists of fission-product radiation from fallout and radiation from neutron-induced activity. The decay rate of the residual radiation from fallout will follow approximately the expressions:

$$I_t = I_1 t^{-1.2} \tag{1.1}$$

and

$$r = \int_{t_1}^{t_2} I_t \, dt = 5I_1 (t_1^{-0.2} - t_2^{-0.2})$$

Where: I_t = exposure rate at time t

I_1 = exposure rate at unit time

t = time

r = exposure between times t_1 and t_2, where t ≥ 10 seconds.

It is expected that the decay of the residual radiation will vary with device design. For example, the presence of Np^{239} would tend to decrease the absolute value of the decay exponent for a period of time.

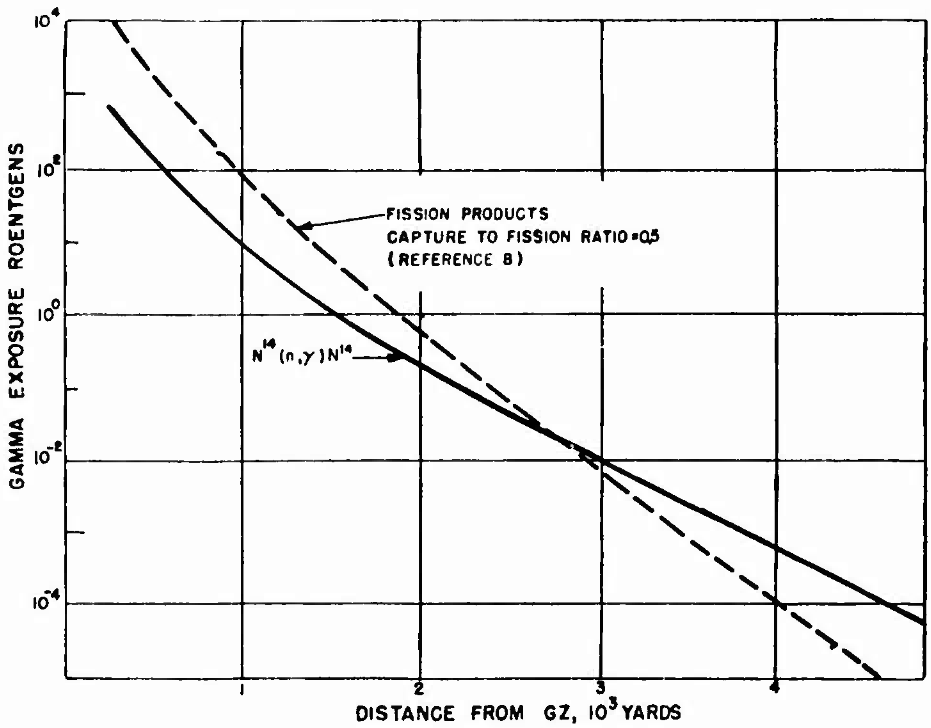

Figure 1.1 Gamma exposure for 1 kt surface burst.

1.3.3 Absorption in Air. The absorption of unscattered gamma radiation in air is exponential with distance. From a point source of mono-energetic radiation, the variation of intensity with distance is expressed as:

$$I_D = \frac{I_0 e^{-\mu D}}{4\pi D^2} \tag{1.2}$$

Where: I_D = intensity at distance D

I_0 = source intensity

μ = linear absorption coefficient (this varies with gamma energy, and is generally lower for higher energies).

D = distance

The absorption coefficient μ in Equation 1.2 is applicable for narrow-beam geometry, and a correction should be made for field conditions where the detector is approximately a 2π sensing element. This is done by adding a buildup factor B to Equation 1.2, to account for the scattered radiation that will be detected. Buildup factors for different energies and distances have been calculated (Reference 11), and some values are shown in Table 1.2. For omni-directional detectors, the expression is:

$$I_D = \frac{I_0 B e^{-\mu D}}{4\pi D^2} \tag{1.3}$$

1.3.4 Hydrodynamic Effect. As shown in Section 1.3.3, the attenuation of gamma radiation is highly dependent on the amount of absorber between the source and the detector. For devices of

TABLE 1.2 CALCULATED BUILDUP FACTORS

The buildup factor B given here is the factor B_r ($\mu_0 D$, E_0) as computed by Nuclear Development Associates for AFSWP (Reference 9).

Energy (E_0) Mev	B 1,000 yds	1,500 yds	3,000 yds
1	16.2	29.3	85.0
3	3.85	5.35	10.2
4	2.97	4.00	7.00
10	1.70	2.01	2.90

less than 100-kt yield, essentially all the initial-gamma radiation is emitted before the shock front can produce an appreciable change in the effective absorption of the air between source and detector. For high-yield devices, the velocity of the shock front is sufficiently high to produce a strong enhancement of a large percentage of the initial-gamma radiation (Reference 10). The higher the yield, the larger is this percentage. A simplified treatment of the hydrodynamic effect follows.

Assume a sphere that has a volume V_0 and radius R, and is filled with a gas of density ρ_0 and mass M. Then,

$$M = V_0 \rho_0 = \frac{4\pi R^3 \rho_0}{3} \tag{1.4}$$

Let the gas be compressed into a shell with thickness ΔR (R remaining constant). The new gas volume is expressed as V_1 with a density of ρ_1 ($V_1 = 4\pi R^2 \Delta R$). The mass has not changed; thus

$$M = V_0 \rho_0 \doteq 4\pi R^2 \Delta R \rho_1 (\Delta R << R)$$

$$\frac{4\pi R^3 \rho_0}{3} \doteq 4\pi R^2 \Delta R \rho_1 \tag{1.5}$$

$$\Delta R \rho_1 \doteq \frac{R \rho_0}{3} \tag{1.6}$$

Equation 1.6 indicates that a ray originating in the center of the sphere would traverse only ⅓ of the mass in the shell model that it would in the homogeneous model. The result would be an enhancement of radiation. Once the shell of material in the shock front passes the detector, an even greater enhancement results.

As previously stated, the N^{14} (n, γ) N^{15} component of initial radiation is essentially emitted within 0.2 second. Since it takes at least 1 second for the shock front to reach a detector at a distance of 7,000 feet (even for devices in the order of 6 Mt), the N^{14} (n, γ) N^{15} component is not significantly enhanced. The fission-product gammas continue to contribute for the first 30 seconds. Therefore, this radiation is strongly enhanced by the shock wave.

TABLE 3.1 SHOT CHEROKEE DATA

Station Number	Location	Slant Distance	Exposure in NBS Holder	Exposure no NBS Holder
		ft	r	r
112.01	Charlie	19,980	—	0.39
113.01	C-D Reef*	18,360	0.45	0.42
113.02	C-D Reef*	17,860	0.47	0.59
113.03	C-D Reef*	17,100	0.80	0.96
113.04	C-D Reef*	17,300	0.51	0.70
113.05	C-D Reef*	17,970	0.22	0.28
113.06	C-D Reef*	19,120	0.12	0.13

* Charlie-Dog

TABLE 3.2 SHOT ZUNI TOTAL-EXPOSURE

Shot time was 0556, 28 May 1956.

Station	Location	Date	Recovery Time	Rate	Total Gamma Exposure		
					Film	Quartz Fiber	Chemical
				mr/hr	r	r	r
212.01	Able	31 May	0925	1,000	202	221	237
212.02	Charlie	31 May	0920	800	155	135	200
212.03	Dog	31 May	0915	1,200	185	195	262
212.04	Easy	31 May	0910	1,200	152	185	—
212.05	Fox	31 May	0905	1,200	207	222	—
212.06	George	31 May	0900	1,200	118	124	92
How	How	31 May	0845	330	44	60	—
Nan	Compound	28 May	1400	0	0.31	—	—
Nan	Airstrip	28 May	1430	0	0.31	—	—
210.22	Oboe Reef	31 May	1030	50	17.5	—	—
210.23	Oboe	29 May	1330	600	93	—	—
210.23'	Oboe	29 May	1330	600	37	—	—
210.24	Oboe Reef	31 May	1030	50	11	—	<50
210.25	Oboe Reef	†	†	†	†	†	†
210.26*	Peter Reef	31 May	1030	50	25	—	<50
210.26*	Peter Reef	31 May	1030	50	69	—	75
210.27*	Peter	29 May	1315	1,200	200	—	220
210.27' *	Peter	29 May	1315	1,200	102	136	125
210.29	Roger	7 June	—	—	2,500	—	—
210.30*	Roger	29 May	1300	1,300	16,000	—	-
210.31	Roger	†	†	†	†	†	†
210.32	Uncle	†	†	†	†	†	†
210.33*	Uncle Reef	30 May	1300	50	1,800	—	850
210.34*	Uncle	29 May	1230	1,000	465	—	420
210.34' *	Uncle	29 May	1230	1,000	335	368	—
210.35*	Uncle Reef	31 May	1005	20	205	—	—
210.37	William	31 May	1000	420	143	200	225
210.38	Yoke	31 May	0950	300	100	120	125
210.39	Zebra	31 May	0945	260	92	108	118
210.40	Alfa	31 May	0940	320	110	118	75
210.41	Bravo	31 May	0935	220	85	100	75

* These stations received both initial and residual radiation as shown in Table 3.3. All other exposures are residual only.

† Destroyed.

TABLE 3.3 SHOT ZUNI INITIAL-GAMMA EXPOSURE

All of the data in this table are from film at aluminum stations except those referred to in * and †.

Station Number	Location	Distance	Total Exposure	Estimated Residual Exposure	Resultant Initial Exposure
		ft	r	r	r
210.30	Roger	7,000	16,000	150	15,850
210.29	Uncle Reef	8,500	2,500	15	2,485
210.33	Uncle Reef	9,420	1,880	15	1,785
210.33	Uncle Reef	9,420	850*	15	835
210.34	Uncle	10,320	465	150	315
210.35	Uncle Reef	10,935	205	15	190
210.27	Peter	11,270	200	150	50
210.27'	Peter	11,270	145†	100	45
210.56	Peter Reef	11,510	69	15	54
210.26	Peter Reef	12,940	25	15	10

* These data are from a chemical dosimeter.

† These data are from a quartz fiber exposure versus time device in a steel station.

TABLE 3.4 SHOT FLATHEAD FOX-COMPLEX INSTRUMENTATION AND RECOVERY

Shot time was 0626, 12 June 1956.

Station Number	Location	Instrumentation		Recovery	
		Date	Time	Date	Time
213.01	MM3	8 June	1350	16 June	1430
212.03	Dog	6 June	1045	14 June	1545
213.02	Dog	8 June	1400	14 June	1530
211.01	Dog	6 June	1115	14 June	1524
213.03	Easy	8 June	1445	14 June	1518
211.02	Easy	6 June	1210	14 June	1515
212.04	Easy	9 June	1200	14 June	1512
211.03	Fox	6 June	1320	14 June	1505
212.05	Fox	6 June	1345	14 June	1405
213.04	Fox	No Record	—	14 June	1400
211.04	George	No Record	—	No Record	—
211.06	George	No Record	—	No Record	—

not fully understood. At Station 212.05 the 10-r thermal and blast exposures were the result of residual contamination from Shot Zuni. Film indicated about [redacted] initial exposure, and quartz-fiber dosimeters indicated about [redacted] The switches in the mechanical drop devices at Stations 213.02, 213.03, and 213.04 functioned, but the dosimeters did not fall below the surface because of a constriction in the pipes.

Table 3.6 and Figure 3.1 give results from the quartz-fiber rate devices for exposure versus time.

The rate device at Station 211.01 did not drop; therefore it was necessary to subtract the residual exposure of [redacted]. At Station 210.02, it was assumed that the [redacted] that arrived after 15 seconds was residual since the shielding was only 90 percent effective. The device at Station

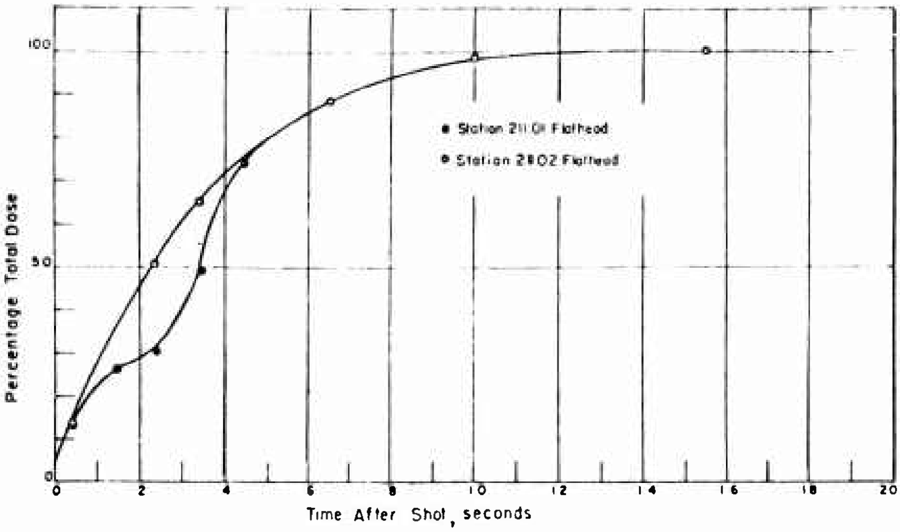

Figure 3.1 Initial-gamma exposure versus time for quartz fiber rate device.

212.04 operated in reverse, yielding only total residual information. The exposure at Station 211.03 was small and could not be resolved properly.

Table 3.7 lists installation, recovery, and residual exposure information. Project 2.2 information indicated that Stations 210.23 to 210.41 received about [redacted] of fallout exposure from this shot, the remainder having come from Shot Zuni.

3.5 SHOT DAKOTA

Tables 3.8 and 3.9 list instrumentation and recovery and initial exposure, respectively, for Shot Dakota. High residual-gamma exposure rates resulted from Shot Flathead at the time of the Shot Dakota instrumentation. Therefore, it was necessary to keep the instrumentation to a minimum. The project was not aware of the change in shot coordinates at the time of instrumentation, and since the shot was moved about $\frac{1}{2}$ mile closer to the Fox complex, the lowest initial exposure recorded was about [redacted]

Dosimeters were placed in two locations on Man-Made Island No. 3 prior to Shot Flathead. One group of dosimeters was found during Flathead recovery, and the second group was recovered after Shot Dakota. A Shot Dakota data point was obtained by subtracting the Shot Flathead exposure.

3.6 SHOT NAVAJO

Tables 3.10, 3.11, and 3.12 list instrumentation and recovery, initial-gamma exposure, and residual exposure, respectively, for Shot Navajo. Some phenomenon, perhaps the shock, caused

Pg. 32 Deleted.

TABLE 3.8 SHOT DAKOTA INSTRUMENTATION AND RECOVERY

Shot time was 0606, 26 June 1956.

Station	Instrumentation			Recovery	
Number	Location	Date	Time	Date	Time
212.03	Dog	16 June	1510	5 July	0925
211.01	Dog	16 June	1515	5 July	0930
211.02	Dog-Easy	16 June	1520	5 July	0935
212.04	Easy	16 June	1525	5 July	0940
213.01	Man-Made 3	8 June	1400	5 July	0920

all the quartz-fiber dosimeters in the rate devices to activate at an early time. As a result, they yielded only total initial plus residual exposure data. Station 211.01 was partially blown out of the ground. The rate device did not drop, thus the station yielded only total initial plus residual exposure information. The 1-minute drop timers were corroded and did not function. Consequently, the estimates of residual exposure on Sites Dog and Easy were not accurate.

3.7 SHOT TEWA

Table 3.13 gives Shot Tewa instrumentation and recovery data, and Table 3.14 shows residual-exposure data. Data from the Charlie-Dog reef, including scattered initial-gamma data is listed in Table 3.15.

Total-gamma exposures at Stations 113.03 and 113.09 were well established. Residual-exposure estimates were obtained from Stations 113.02 and 113.03. These stations were in the same general

TABLE 3.9 SHOT DAKOTA INITIAL EXPOSURE

Shot time was 0606, 26 June 1956.

Station Number	Timing	Film Exposure	Calculated Preshot Residual	Estimated Postshot Residual	Initial	Distance
		r	r	r		ft
212.03	Total Blast	1.17×10^5 1.67×10^4	105	50	1.17×10^5	4,422
211.01	Total Blast	2.48×10^4 4,600	90	50	2.47×10^4	5,500
213.01	Total	5,175 †	15	25	5,135	6,605
211.02	Total Blast	4,600 1,060	65	50	4,485	6,650
212.04	Total 1 minute	880 830	65	50 *	705	7,220

* This result was obtained by subtracting the 1-minute value from the total value. The other estimates were based on this value.

† This result was obtained by subtracting the total Flathead exposure value of 725 r from the Flathead plus Dakota exposure value of 5,900 r.

area and had the same geometry and recovery rates but were in a region where the initial-gamma exposures were negligible. Film at Stations 113.04, 113.07, and 113.08 read greater than 70,000 r. The chemical data at 113.04 appeared valid. The chemical data at Station 113.08 was probably in error, since it contradicted both the film data at Station 113.08 and the chemical data at Station 113.04, and was far below the predicted level. The exposures expected at Station 113.07 were far above the useful range of the chemical dosimeters and it is probable that they saturated, and that the actual exposure was much greater than 650,000 r. There was no satisfactory explanation for the discrepancies that occurred in the chemical data derived from Stations 113.07 and 113.08. The discrepancies observed in the chemical data from 113.07 and 113.08 suggested that the reliability of the chemical dosimeter systems might have been questionable when they were used in the environment which existed at Stations 113.04, 113.07, and 113.08. These chemical dosimeters were exposed to a total gamma dose that was much higher than their upper range, and they were probably exposed at a very high dose rate and to a very high neutron flux.

It was felt that the initial-exposure data from 113.03 was reliable since the total exposure was well established and the residual estimate was valid. Data from Stations 113.03, 113.04, and 113.09 agreed with results from previous events.

TABLE 3.10 SHOT NAVAJO INSTRUMENTATION AND RECOVERY

Shot time was 0556, 11 July 1956.

Station Number	Location	Instrumentation Date	Instrumentation Time	Recovery Date	Recovery Time
210.19	Fox	7 July	1530	13 July	1108
210.20	George	7 July	1540	13 July	1050
210.23	Oboe	5 July	0750	13 July	1132
210.27	Peter	5 July	0755	13 July	1125
210.30	Roger	5 July	0800	13 July	1120
210.34	Uncle	5 July	0808	13 July	1110
210.37	William	5 July	0815	13 July	1100
210 38	Yoke	5 July	0822	13 July	1025
210.39	Zebra	5 July	0827	13 July	1015
210.40	Alfa	5 July	0832	13 July	1010
210.41	Bravo	5 July	0835	13 July	0958
212.01	Able	5 July	0848	13 July	0945
212.02	Charlie	5 July	0857	13 July	0930
113.07	M M No. 1	5 July	0905	13 July	0922
113.08	M M No. 2	5 July	0910	13 July	0920
113.09	M M No. 3	5 July	0920	13 July	Destroyed
212.03	Dog	7 July	1420	13 July	1425
212.04	Easy	7 July	1230	13 July	1315
212.05	Fox	7 July	1125	13 July	1117
212.06	George	7 July	1000	13 July	1000
211.01	Dog	7 July	1400	13 July	1405
211.02	Dog-Easy	7 July	1335	13 July	1355
211.03	Easy-Fox	7 July	1340	13 July	1240
211.04	Fox-George	7 July	1020	13 July	1055
213.02	Dog	7 July	1410	13 July	1415
213.04	Fox	7 July	1040	13 July	1110

TABLE 3.13 SHOT TEWA INSTRUMENTATION AND RECOVERY

Shot time, 0546, 21 July 1956.

Station	Location	Position	Instrumentation Date	Instrumentation Time	Instrumentation Rate	Recovery Date	Recovery Time	Recovery Rate
					mr/hr			mr/hr
212.01	Able	Front	15 July	1010	90	24 July	1420	4,000
		Right	—	—	90	—	—	—
		Rear	—	—	90	—	—	—
		Left	—	—	90	—	—	—
212.02	Charlie	Front	15 July	1000	32	24 July	1425	3,000
		Right	—	—	47	—	—	—
		Rear	—	—	38	—	—	—
		Left	—	—	27	—	—	—
113.01	Charlie-Dog Reef	—	16 July	1645	4	25 July	1750	8
113.02	Charlie-Dog Reef	—	16 July	1625	3	25 July	1755	20
113.03	Charlie-Dog Reef	—	16 July	1600	3	25 July	1810	40
113.04	Charlie-Dog Reef	—	16 July	1510	4	25 July	1825	18
113.05	Charlie-Dog Reef	—	16 July	1440	0 to 2	25 July	Destroyed	
113.07	M M No. 1	—	16 July	1400	90	25 July	1100	1,000
113.08	M M No. 2	—	16 July	1250	120	24 July	1430	2,800
113.09	M M No. 3	—	16 July	1200	80	25 July	1115	3,500
212.03	Dog	Front	15 July	0945	80	25 July	0930	1,500
		Right	—	—	100	—	—	—
		Rear	—	—	100	—	—	—
		Left	—	—	70	—	—	—
212.04	Easy	Front	15 July	0950	60	24 July	1050	2,400
		Right	—	—	80	—	—	—
		Rear	—	—	100	—	—	—
		Left	—	—	60	—	—	—
212.05	Fox	Front	15 July	0935	60	24 July	1110	3,000
		Right	—	—	65	—	—	—
		Rear	—	—	70	—	—	—
		Left	—	—	60	—	—	—
212.06	George	Front	15 July	0925	30	24 July	1120	1,000
		Right	—	—	45	—	—	—
		Rear	—	—	70	—	—	—
		Left	—	—	45	—	—	—
210.23	Oboe	—	15 July	1105	8	24 July	1320	6
210.27	Peter	—	15 July	1100	4	24 July	1330	8
210.30	Roger	—	15 July	1056	9	24 July	1335	18
210.34	Uncle	—	15 July	1047	4	24 July	1342	220
210.37	William	—	15 July	1038	8	24 July	1350	1,000
210.38	Yoke	—	15 July	1033	5	24 July	1355	1,000
210.39	Zebra	—	15 July	1030	9	24 July	1400	1,500
210.40	Alfa	—	15 July	1025	8	24 July	1402	2,200
210.41	Bravo	—	15 July	1020	7	24 July	1404	2,200

Pg. 37 Deleted.

TABLE 3.14 SHOT TEWA RESIDUAL EXPOSURE

Station Number	Exposure Quartz Fiber	Position	Film	Position
	r		r	
210.23	3.8	—	2.51	—
	2.0	rear	—	—
210.27	6.5	—	3.67	—
210.30	8.2	—	6.45	—
210.34	98	—	82.6	—
	160	rear	93.5	rear
210.37	510	—	391	—
210.38	525	—	454	—
210.39	800	—	627	—
210.40	1,300	—	1,045	—
210.41	825	—	755	—
212.01	2,300	—	2,833	front
	—	—	1,916	right
	—	—	3,016	rear
	—	—	2,400	left
212.02	890	—	823	—
	2,650	rear	1,000	front
	—	—	1,485	right
	—	—	1,460	rear
	—	—	940	left
212.03	695	—	610	—
	1,102	rear	580	front
	—	—	920	right
	—	—	860	rear
	—	—	762	left
212.04	510	—	375	—
212.05	521	—	399	—
	1,027	rear	700	front
	—	—	710	right
	—	—	668	rear
	—	—	640	left
212.06	240	—	201	—

TABLE 3.15 SHOT TEWA INITIAL-GAMMA EXPOSURE

Station	Distance	Total Dose Film	Total Dose Chemicals	Estimated Residual	Initial
	ft	r	r	r	r
113.01	15,850	160	250	160 to 250	—
113.02	14,380	250	250	250	—
113.02	14,380 *	400	—	400	—
113.02	14,380 *	580	—	580	—
113.02	14,380 *	820	—	820	—
113.03	10,500	3,300	2,500	250	2,650
113.04	6,760	$>7 \times 10^4$	3.35×10^5	250	3.35×10^5
113.05		Destroyed			
113.06		Destroyed - Not Instrumented			
113.07	2,875	$>7 \times 10^4$	6.5×10^5†	800	Very great
113.08	5,940	$>7 \times 10^4$	42,000‡	800	$>7 \times 10^4$
113.09	10,830	1,950	—	800	1,150

* These films were located on the outside of the steel-pipe stations. All other dosimeters were located inside the stations.

† Exposures anticipated at this station were far above the intended range of this dosimeter, and the instrument probably saturated.

‡ As indicated in the text, this is probably in error. No explanation can be offered as to why this reading is lower than that of 113.04.

3.8 DISCUSSION

Table 3.16 summarizes Operation Redwing initial-gamma exposure data, and Table 3.17 gives the total yield, fission yield, and relative air density for each event. Figures 3.2, 3.3, and 3.4 are plots of the Redwing initial-gamma exposure versus distance and the TM 23-200 curves for similar total yield. This method of computation neglects the effect of relative fission and fusion contributions to the total yield. Correction factors discussed in Section 2.3.1 have been applied to adjust the raw data to unshielded, betatron-calibrated exposure values. Shot Cherokee data were adjusted to relative air density of 0.895. The initial-gamma exposure from Shots Cherokee, Zuni, and Navajo at 3 miles was about 1 r. The accuracy of the initial-gamma exposure data as corrected was within ± 30 percent.

Figures 3.5 through 3.8 show the total residual-gamma exposures plotted on maps. These exposures were corrected for station shielding and spectral response of the dosimeters (Section 2.3.2). In addition, all the values from a given shot were adjusted to the same recovery time using recovery rates, and assuming a decay exponent of -1.2. Individual stations, such as the one on Site Charlie, may have shown reduced amounts of exposure because they were near the lagoon. The accuracy of the residual-gamma data presented in this section was within ± 50 percent.

TABLE 3.16 REDWING INITIAL-GAMMA EXPOSURE

Shot	Station	Uncorrected Initial	Combined Correction Factor	Corrected Initial	Distance
Zuni	210.30	15,850	1.0	15,850	7,000
	210.29	2,485	1.0	2,485	8,500
	210.33	835	1.0	835	9,420
	210.34	315	1.0	315	10,320
	210.35	190	1.0	190	10,935
	210.56	54	1.0	54	11,510
	210.26	10	1.0	10	12,940
Tewa	113.04	3.35×10^5	1.21	4.05×10^5	6,760
	113.03	2,650	1.1	2,915	10,500
	113.09	1,150	1.1	1,265	10,830

* Cherokee exposure adjusted to 0.895 relative air density.
† Station contained a rate device.

TABLE 3.17 YIELDS AND RELATIVE AIR DENSITIES

Shot	Total Yield, Mt	Relative Air Density
Cherokee		0.847
Zuni	3.53	0.894
Flathead		0.896
Dakota		0.893
Navajo		0.895
Tewa	5.01	0.893

Pg. 42 Deleted.

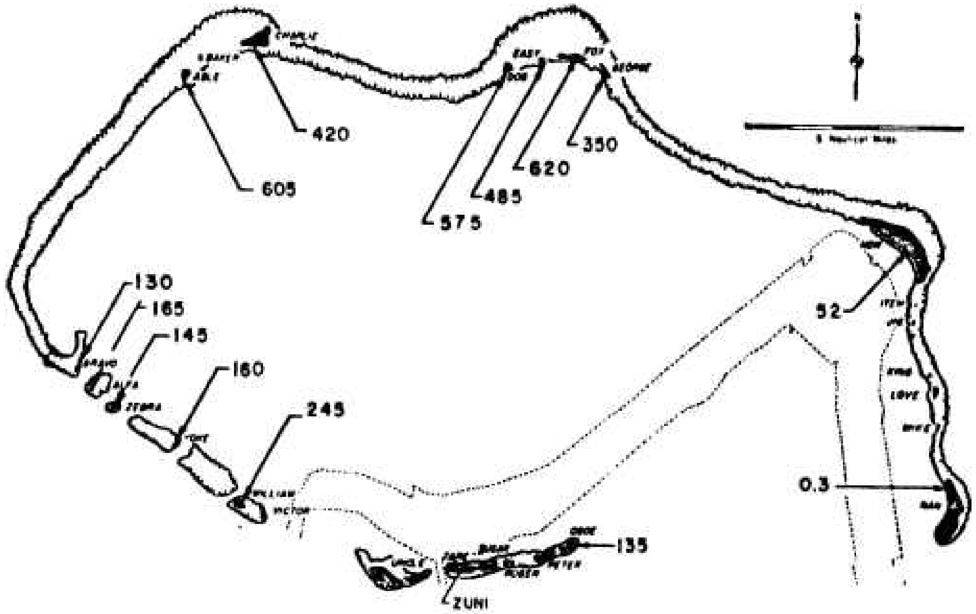

Figure 3.5 Shot Zuni 76-hour residual exposure (roentgens).

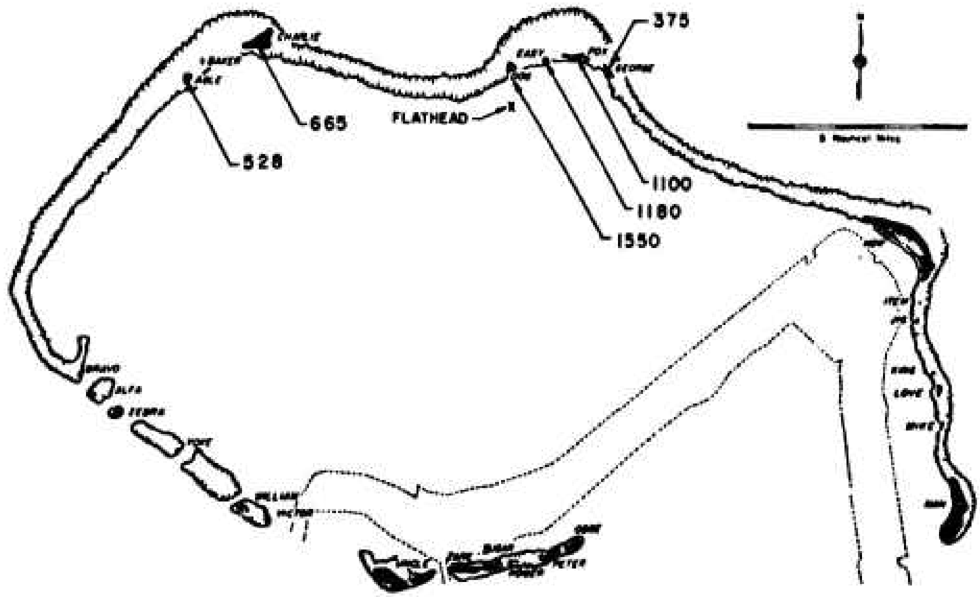

Figure 3.6 Shot Flathead 72-hour residual exposure (roentgens).

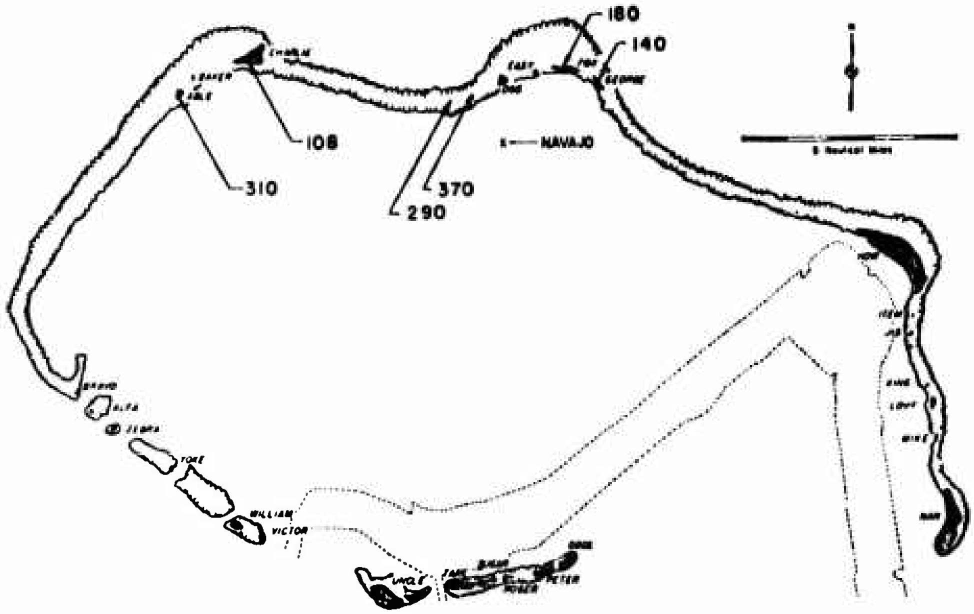

Figure 3.7 Shot Navajo 48-hour residual exposure (roentgens).

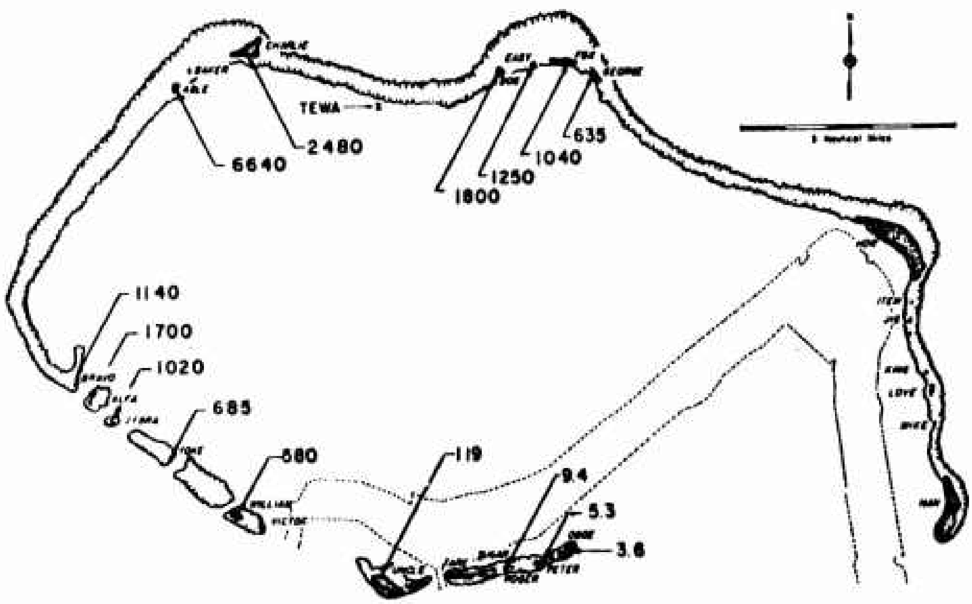

Figure 3.8 Shot Tewa 78-hour residual exposure (roentgens).

The data from this project are presented to indicate the approximate magnitude of the residual-gamma radiation to be expected from different types of nuclear devices. It is felt that with the exception of Shot Cherokee (for which insufficient data were obtained to form definite conclusions) the objectives of the project were met.

In the case of Shot Cherokee, the burst point was approximately 4 to 5 miles in the downwind direction away from the planned ground zero; this resulted in no downwind stations to document residual radiation from fallout. The ground zero for Shot Tewa was moved from its planned location off Site Dog to a location approximately between Sites Charlie and Dog. It was therefore necessary to improvise stations at available locations on the man-made islands and the reef between Sites Charlie and Dog. Data points were obtained at distances of about 3,000, 7,000, and 10,000 feet, where the initial could be separated from the residual radiation.

In order to compare this project's initial-gamma data with data from previous high-yield shots, reference is made to the Nuclear Radiation Handbook (AFSWP-1100, Figure 3.2.6, page 65), which gives experimental values of DR^2/W for various high-yield shots of Operations Greenhouse, Ivy, and Castle as compared to average values for a large number of low- and intermediate-yield (0 to 100 kt) shots. With the data of this figure as background, additional data from Redwing Shots Flathead, Zuni, Navajo, and Dakota, and Castle Shot Nectar are shown (Figure 3.9). The curves shown for Shots Flathead, Zuni, Navajo, Dakota, and Nectar are the lines of the least-square fit to the DR^2/W-versus-R data normalized (at 2,000 yards) for a relative air density of $\bar{\rho} = 1.0$. This normalization was accomplished by adjusting the slope of the data line (while maintaining the zero-intercept constant) in a manner similar to that used in WT-1115 (Reference 3). Examination of the curves shown in Figure 3.9 indicates that project data agrees with data from all previous operations.

The initial-gamma instrument station locations were selected with an expectation of 50 percent loss per shot; however, the losses were only about 25 percent. The residual instrumentation was nearly 100 percent effective. The secondary and improvised instrumentation for separation of initial- from residual-gamma radiation were only about 40 percent effective throughout the operation.

Chapter 4

CONCLUSIONS

Examination of data indicates the following conclusions:

1. For surface bursts with yields from [redacted] to 5 Mt, and for a [redacted] airburst, initial-gamma radiation is of little military significance to unprotected personnel as compared with thermal and blast damage.

2. The amount of residual-radiation exposure is a function of the fission yield.

3. The curves of initial-gamma exposure versus distance obtained from Project 2.1 data vary from corresponding TM 23-200 curves. The field data falls below predictions at longer ranges and is greater than predicted at shorter ranges. This difference between predicted and field data increases with increasing yield.

REFERENCES

1. Capabilities of Atomic Weapons; TM 23-200, prepared by AFSWP; OPNAV INSTRUCTION 003400.1A, AFL 136-4, NAVMC 1104, Department of the Army, the Navy and the Air Force, revised edition, 1 June 1955 with changes of 1 April 1956; Secret Restricted Data.

14. M. Ehrlich; "Photographic Dosimetry of X- and Gamma-Rays"; Handbook 57, 20 August 1954; National Bureau of Standards, Washington, D. C.; Unclassified.

15. M. Ehrlich; "Radiation Sensitivity of Photographic Emulsions"; NBS Reports 8A107 and 8A121; Radiation Physics Laboratory, National Bureau of Standards, Washington, D. C.; Unclassified.

17. A.E. Cohen, M.H. Jachter, and H.M. Murphy, Jr.; "Evaluation of Military Radiac Equipment"; Project 6.1.1a, Operation Teapot, WT-1137, February 1958; U.S. Army Signal Engineering Laboratories, Fort Monmouth, New Jersey; Official Use Only.

18. S.C. Sigoloff, H.M. Borella and J.A. Auxier; "Biological Effects from Massive Doses of Neutron-Gamma Radiation; Dosimetry Report"; USAF Report Number 55-108; School of Aviation Medicine.

19 S.C. Sigoloff; "Fast Neutron Insensitive Gamma Ray Dosimeters; The AC and ATCE Systems"; USAF, In press; School of Aviation Medicine.

23. F.J. Sisk, LCDR, USN, and D.E. Nielsen, 1st Lt., USA; "Evaluation of Military Radiac Equipment"; Project 6.1, Operation Snapper, WT-532, January 1953; U.S. Navy, Bureau of Ships, and U.S. Army, Signal Corps Engineering Laboratories; Unclassified.

24. Radiac Training Sets AN/PDR-T1 . . . AN/PDR-39; TM 11-5514, Department of the Army Technical Manual, dated May 1951, with addendum, dated October 1952. Pages 2, 18, 63, and 64.

25. H.O. Wyckoff and others; "Delayed Gamma-Ray Measurements: Film Dosimeter Measurements"; Scientific Director's Report, Annex 1.2, Part III, Operation Greenhouse, WT-81, May 1952; Radiation Physics Laboratory, National Bureau of Standards, Washington, D.C.; Unclassified.